Perturbed atmosphere

Meteorologists want to know why the wind is so strong on Venus and Titan

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Planet Venus, photographed by the European probe Venus Express: its size is similar to the Earth's, and its winds travel at 400 km/h

The days pass slowly on Venus. The planet rotates notably slowly. Venus is approximately the size of Earth but takes 243 Earth days to make a complete rotation. Because of its slow rotation, meteorologists expected that Venus' atmosphere would be among the calmest in the Solar System. However, the probes that were sent to the planet observed constant wind in the upper atmosphere, where the wind speeds reach 400 km/h. Such intense winds only occur on Earth during hurricanes or sporadically at high altitudes. On Venus, it is always windy, particularly around the equator.

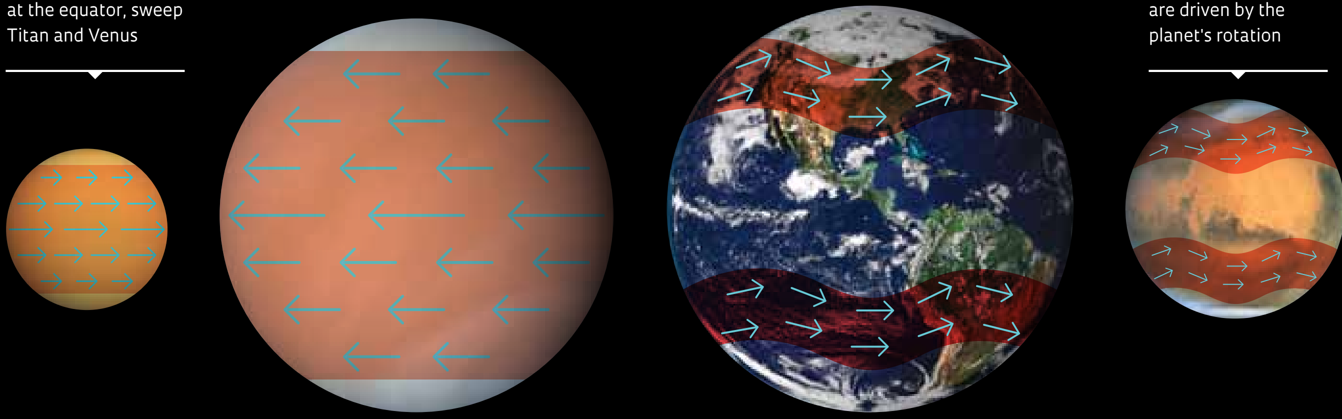
To try to solve this mystery, João Rafael Dias Pinto, a meteorologist at the University of São Paulo (USP), and Jonathan Lloyd Mitchell, a planetary scientist at the University of California, Los Angeles, created a simplified computer model of a planet with an atmosphere. Simulations using this model, which were published in August 2014 in the journal Icarus, are the first to correctly describe how the winds that sweep Venus are maintained. This phenomenon, which is known as atmospheric superrotation, is also observed on Titan, Saturn's largest moon. "We identified new, important mechanisms that help us understand these winds better," says Mitchell.

According to the new model, the secret of superrotation is the manner in which heat is distributed in the atmospheres of Venus and Titan. Through vertical circulation, the heat spreads more slowly upward and toward the poles on Venus and Titan than on Earth. Additionally, a special type of ripple in the atmosphere affects the gas currents.

Venus and Titan are so different from each other that the similar behaviors of their atmospheres appear strange. Venus' surface temperature can reach 477°C because of the greenhouse effect of its atmosphere, which is rich in carbon dioxide gas. On Titan, the temperature is -180°C, and methane rain feeds the lakes on its surface. However, when the space probe Huygens descended to the surface of Titan in 2005, it discovered that the wind profile was almost identical to that on Venus, which was previously observed by the Venera-series Soviet probes in the 1970s and 1980s. Although the winds are weak on the sur-

As the wind blows

The air current regimes on Earth and Mars are milder than those on Venus and Titan



face, the winds at the equators of Venus and Titan reach 360 km/h at an altitude above 50 km, whereas the winds at the identical altitude at the Earth's equator are under 15 km/h.

BEYOND ROTATION

Dias Pinto explains that on Earth, the mass of air that circles the globe is driven by the difference in temperature between the equator and the poles and is dragged along by the rotation of the planet. Thus, meteorologists expected weaker winds on planets and satellites that rotate more slowly. Researchers have been seeking an explanation for superrotation since the 1970s and concluded that in addition to slower rotation, there is probably a specific oscillation pattern in the motion of the atmosphere. This pattern of atmospheric waves helps create an intense air jet that is concentrated at the equator and covers almost all of the celestial body. "It is as if the entire atmosphere moved in a single direction," explains Pinto, "the problem is that most atmospheric models of Venus and Titan, including the most realistic, find it difficult to reproduce superrotation."

Pinto decided to study superrotation during his PhD studies. At a conference in 2011 in France, he met Mitchell, an expert on Titan and Venus who was interested in attacking the problem with a simpler model. "With a more idealized model, I can better control the dynamics of the atmosphere," says Pinto. He worked under the guidance of Mitchell and the Brazilians Rosmeri Porfírio da Rocha and Tércio Ambrizzi, of the USP Institute of Astronomy, Geophysics and Atmospheric Sciences (IAG), and he could simulate superrotation using an atmospheric model for weather forecasting.

By modifying some parameters in this model, Pinto discovered that decreasing the planet rotation was not sufficient to accelerate the rotation of the atmosphere. "João demonstrated that the model only develops superrotation if it transports heat from the equator to the poles more slowly," explains Mitchell, noting that on Venus and Titan, despite the strong winds, the air circulates notably slower in the vertical direction.

Pinto also identified a special form of planetary wave in his simulations, which arises from the oscillations in the air currents at the planet's equator. "These planetary waves are the main drivers and maintainers of superrotation," explains Mitchell.

"These aspects of superrotation have never been analyzed in detail," says Sebastien Lebonnois, a planetary scientist of the National Council for Scientific Research (CNRS) in France who studies the superrotation of Venus and Titan. "To confirm this analysis, we would need wind and temperature observations with a resolution that is difficult to obtain even on Earth." Despite the difficulty, he hopes to obtain evidence from the Venus Express probe data, which is orbiting Venus, or the Cassini orbiter, which is near Titan. ■

Project

Wave-mean flow interaction and atmospheric superrotation in terrestrial planets (Nº. 12/13202-8); **Grant Mechanism** Doctoral Fellowship – Research Internships Abroad; **Principal investigator** Tercio Ambrizzi (IAG/USP); **Grant recipient** João Rafael Dias Pinto; **Investment** R$40,381.84 (FAPESP).

Scientific article

DIAS PINTO, J. R. and MITCHELL, J. L. Atmospheric superrotation in an idealized GCM: Parameter dependence of the eddy response. **Icarus**. V. 238. p.93-109. Aug. 2014.

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